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Structural Model of Molecular Cloud Complexes: Mass, Size, and External Pressure

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We investigate the structure of the molecular cloud complexes (MCCs) as a group of several giant molecular clouds (GMCs) in the Galaxy. Then, we find that the mass-size relation which has been reported for the GMCs establishes well even for the very large MCCs whose size is about 1 kpc. Since the horizontal size of the MCCs is more than the thickness of the Galactic disk, we can no longer consider the MCCs to be a sphere. Thus, we construct a structural model of the MCCs, adopting a rectangular-solid geometry. As a result, our model explains the observed mass-size relation of the MCCs very well. From the estimated external pressure around the MCCs, we find that they are in a rough pressure balance with the interstellar medium. Moreover, we find there is observational deficiency of the MCCs with a large size and surface density. Then, we suggest that the external pressure has a significant effect on the structure and evolution of the MCCs. We also discuss the effect of H ii regions in the MCCs.

hydrodynamics — ISM : clouds — ISM : structure — Galaxy: ISM — stars : formation

headings

Introduction

The star forming regions of the galaxies have a kind of the hierarchical structure; individual stars, H ii regions, OB associations, aggregates, giant molecular clouds (GMCs), and complexes (Elmegreen, Salzer 1999). The star-forming complexes are the regions containing the smaller structures, and their typical size is more than several hundreds parsecs. For example, in our Galaxy, there are star complexes whose averaged diameter is about 600 pc (Efremov 1978). Also, there are H i superclouds which include a group of the GMCs (Elmegreen, Elmegreen 1987). In M51, the existence of the giant molecular associations, whose mass is more than 10^7 , are reported by Vogel, Kulkarni, Scoville (1988) and Rand, Kulkarni (1990). In this *Letter*, we concern such star-forming complexes, especially, the molecular cloud complexes (MCCs) as a group of several GMCs in order to understand the star formation activity over a galactic wide scale. Such MCCs have been observed in our Galaxy (Myers et al. 1986), although they are smaller than the giant molecular associations in M51.

By the way, from many observations of the GMCs, it has reported that there are famous correlations; the size-velocity dispersion relation and the size-mass (or density) relation (e.g., Larson 1981; Myers 1983; Sanders et al. 1985; Dame et al. 1986; Solomon et al. 1987). The former relation implies that the interstellar medium (ISM) is in a turbulent condition. The latter is that the mass of the GMCs is proportional to the square of their size. However, for the MCCs, these empirical correlations mentioned above have not discussed sufficiently to date. Hence, we discuss the mass-size relation (and also surface density-size relation) for the MCCs in this *Letter*.

On the other hand, the famous observational paper by Myers (1978) shows clearly that there is a global pressure balance among the variety components of the ISM. Although Bowyer et al. (1995) shows an evidence for a pressure imbalance in the local (40 pc) ISM, such a pressure balance can be still acceptable in a galactic scale. Thus, a kind of the pressure equilibrium is often adopted to examine the structure and evolution of any component of the ISM. Indeed, the criterion of the gravitational contraction of the self-gravitating clouds is affected by the external pressure around them (e.g., Ebert 1955; Bonnor 1956; Nakano 1998). Thus, we should always pay a part of our attention to the importance of this external pressure.

Assuming such an pressure equilibrium and a spherical geometry, the structure and the empirical correlations among mass, size, and velocity dispersion of the GMCs are studied very well (e.g., Chièze 1987; Maloney 1988; Elmegreen 1989; McKee, Holliman 1999). The assumption of the spherical structure for each GMC is not so crucial statistically if the number of sample clouds is sufficient. However, it is not good for the MCCs. Indeed, the MCCs are not spherical (see, for example, Figure 3 of Myers et al. 1986), and their horizontal size is about or above the thickness of the disk of the host galaxies. In this *Letter*, therefore, we investigate the structure of the MCCs, adopting not spherical geometry model.

In the next section, we summarize the property of the data adopted in our discussions. Our model is described in section 3. The results and discussions are presented in section 4, and the summary is presented

in the final section.

Data Properties

We need a large sample of the MCCs, to obtain their clear and convincing property as a general picture. Furthermore, it is better that the sample MCCs are relatively similar each other. Then, we choose the MCCs in the Galaxy as the sample for our analysis. The suitable data of the MCCs are compiled in Myers et al. (1986).

Myers et al. (1986) examined 54 molecular clouds and cloud complexes in the Galactic disk. These clouds and complexes locate in $-1^\circ \leq b \leq 1^\circ$, $12^\circ \leq l \leq 60^\circ$. The MCCs contain typically five local maxima of the observed CO intensity in themselves. Solomon et al. (1987) observed the same region and detected 273 GMCs. These two observations are supplemented each other because of their different spatial resolution. For example, Solomon's No.45, 48, 49, and 56 objects seem to correspond to Myers' 17,58 objects. Also, Myers et al. (1986) examine whether individual clouds and MCCs are associated with H ii regions. Some properties of their sample are tabulated in their Table 2.

The mass of each MCC was estimated from the integrated CO intensity over its observed area by using a standard CO-H₂ conversion factor ($2 \times 10^{20} \text{ cm}^{-2} [\text{K km s}^{-2}]^{-1}$ of Lebrun et al. 1983). The derived observational masses distribute over the range of 10^{4-7} , and the median value is 6.3×10^5 .

We can observe the projected size of the MCCs perpendicular to the line of sight. In this *Letter*, we define a horizontal size of each MCC, l , by the following equation, equation 1= $D \tan \delta l$ [pc],



